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Effect of drought stress and potassium foliar application on some physiological indices of three wheat (*Triticum aestivum* L.) cultivars

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ABSTRACT

In order to evaluate the effect of drought stress and potassium foliar application on some physiological indices of three wheat (Triticum aestivum L.) cultivars, an experiment was conducted at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj, Iran. The experimental factors included three irrigation regimes, control (complete irrigation), mild stress (withholding irrigation at grain filling phase) and severe stress (withholding irrigation at ear emergence phase), potassium foliar application, without foliar application, 1.5% and 3.0% K2O and three wheat cultivars (Marvdasht, Pishtaz and WS-82-9). The experiment was carried out in a split plot factorial design based on randomized complete blocks with three replications. Net photosynthesis, leaf stomatal conductance, transpiration rate were measured at two stages; after ear emergence and grain filling stages. In the first measurement of physiological indices, there were no significant differences between drought stress, potassium foliar application and cultivars or for their interaction. Whereas, in the second measurement, net photosynthesis, stomatal conductance, transpiration rate were significantly decreased by drought stress. Also these traits showed significant increase by increasing potassium foliar application. Pishtaz cultivar was better than other cultivars in net photosynthesis.

Key words: Wheat, drought stress, Potassium foliar application, Physiological indices.

INTRODUCTION

Among the environmental stresses, drought is one of the most severe stresses for plant growth and productivity [1]. In Iran, agriculture is expected to face less and less water availabilities in the near future. During grain filling in wheat, plants are subjected to some unfavorable conditions such as low winter rainfall, shortage of water irrigation and the need to withholding irrigation for saving water and early land evacuation for cultivating the following crop [2]. The effect of drought stress on the plant growth process has been extensively reported [3, 4]. Drought affects nearly all the plant growth processes; however, the stress response depends upon the intensity, rate, and duration of exposure and the stage of crop growth [5]. The response of a plant to environmental stress is determined by its nutritional status. One of the mechanisms for improving plant tolerance to drought is to apply K which seems to have a beneficial effect in overcoming soil moisture stress. Potassium plays a vital role in: photosynthesis, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and, many other processes [6, 7]. Increased application of K has been shown to enhance photosynthetic rate, plant growth and yield in different crops under water stress conditions [8, 9, 10, 11]. Foliar fertilization of crops can complement and guarantee the availability of nutrients to crops for obtaining higher yields [12]. Spraying wheat plants with K before subjecting the plants to drought treatment diminished the negative effects of drought on growth and in turn increases yield per plant [13].

The objective of this study was to find out the effects of drought stress and potassium foliar application on physiological indices of three cultivars of wheat.

MATERIALS AND METHODS

A field experiment was conducted in 2011-2012 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj, Iran. Experimental design was a split factorial arrangement based on randomized complete block with three replications. Three irrigation regimes, control (complete irrigation), mild stress (withholding irrigation at grain filling phase) and severe stress (withholding irrigation at ear emergence phase), potassium foliar application, without foliar application (K0), 1.5% (K1) and 3.0% K2O (K2) and three wheat cultivars (Marvdasht, Pishtaz and WS-82-9) comprised the experimental factors. Seeds of three wheat (*Triticum aestivum* L.) cultivars were sown on 18 November. Sowing density was 400 seeds m^{-2} by planting 500 seeds on each row. Plots were 5 m long and 2 m wide, with eight rows 0.25 m apart. All plants received irrigation until the imposition of treatments. Drought treatments imposed by withholding irrigation after ear emergence and grain filling phases. Urea and super-phosphate were applied according to results of soil analysis. All plots received one-third of urea and all super-phosphate at sowing. Other two-third of urea was applied at the start of stem elongation, and before flowering, respectively. Plots for potassium foliar application treatments were assigned to three levels of treatments *i.e.* control treatment (without spraying), 1.5 and 3.0 % K2O in the form of potassium sulphate (48 % K2O). The foliar solution was prepared at both rates and applied using hand sprayer at steam elongation stage. Measurements of physiological traits were made at a fix time of day between 9.00 to 12.00 h at two growth stages, 1. after withholding water at ear emergence stage 2. after withholding water at grain filling stage. The youngest fully-expanded leaf (third from the apex), intact and full sunlit leaves per plot was used for measurements. Physiological traits were measured by the CI-340 Ultra-Light Portable Photosynthesis System. Measurements obtained by using Leaf Chamber attachments in conjunction with the CI-340. It contains a pump along with a mass airflow sensor. A built-in microprocessor regulates the airflow rate, which is set by the user. Analysis of variance was carried out using SAS software. Treatment means were compared using Duncan's test at the 5% and 1% levels of significant.

RESULTS AND DISCUSSION

The effects of irrigation withholding and potassium foliar application on physiological indices of three wheat cultivars are shown in table 1. In the first measurement of physiological indices, there were no significant differences between drought stress, potassium foliar application and cultivars or for their interaction. Whereas, in the second measurement net photosynthesis, leaf stomatal conductance and transpiration rate were significantly affected by drought stress and potassium foliar application (Table 1).

Table 1. Net photosynthesis, leaf stomatal conductance and transpiration rate of three wheat cultivars in response to drought stress and potassium foliar application at two growth stages.

Source of variance	Mean of square					
	after ear emergence stage			after grain filling stage		
	Net photosynthesis	Transpiration rate	Leaf stomatal conductance	Net photosynthesis	Transpiration rate	Leaf stomatal conductance
Block	1.6173	0.0741	33.9993	1.1297	0.4886	13.3743
Drought stress (D)	4.3834	0.8229	16.0973	14.7126 **	3.6370 **	112.2149 **
Potassium foliar application(K)	0.1813	0.0046	2.1630	4.5814 **	4.3947 **	215.6657 **
Cultivar(C)	0.4256	0.0358	4.5607	1.5002 *	0.0096	0.3568
(D×K)	0.8035	0.0397	2.5754	0.1652	0.0452	2.6498
(D×C)	0.1592	0.0726	1.6317	0.4818	0.0936	2.4541
(K×C)	0.0755	0.0196	2.3956	0.3564	0.0480	2.3609
(D×K×C)	0.1440	0.0400	2.7030	0.3983	0.0459	1.4016
Error	0.3161	0.0301	3.2512	0.3284	0.0788	4.7194
CV%	18.68	8.96	15.64	27.07	17.99	23.88

** and **, significant at the 0.05 and 0.01 levels of probability, respectively*

Net photosynthesis significantly decreased by increasing drought stress and this reduction was %66 (Table 2). Siddique, *et al*., (1999) in similar study on wheat reported that both vegetative and anthesis stages, water deficit significantly decreased net photosynthesis. The reduction in net photosynthesis due to drought stress was more severe at the anthesis (80%) than at the vegetative (65%) stage [14]. In present study, stomatal conductance and transpiration rate significantly decreased by increasing drought stress and this reduction were %53.4 and %55, respectively (Table 2). Similar results were recorded by Siddique, *et al*., (1999) who reported that water deficit significantly decreased Stomatal conductance both at the vegetative and anthesis stages. Stress induced reductions in Stomatal conductance were 60% and 50% for vegetative and anthesis drought, respectively as compared with the control treatment [14]. In other experiment on oil seed species (*Brassica napus*), leaf stomatal conductance consistently decreased under water stress in both species and sampling stages [1].

Table 2. Means comparison of some physiological traits of three wheat cultivars in response to drought stress and potassium foliar application at two growth stages.

Treatments	Traits					
	after ear emergence stage			after grain filling stage		
	Net photosynthesis (μ mol co2/m^{2}s)	Transpiration rate (m mol /m^{2}s)	Leaf stomatal conductance (m mol /m^{2}s)	Net photosynthesis (μ mol co2/m^{2}s)	Transpiration rate (m mol /m^{2}s)	Leaf stomatal conductance (m mol /m^{2}s)
Drought stress						
Control	12.30 ^{a}	4.55 ^{a}	161.84 ^{a}	9.27 ^{a}	4.12 ^{a}	145.38 ^{a}
Mild stress	9.04 ^{a}	3.73 ^{a}	132.87 ^{a}	3.77 ^{b}	2.21 ^{b}	72.35 ^{b}
Severe stress	7.29 ^{a}	3.20 ^{a}	119.03^a	3.09 ^{b}	1.85 ^{b}	67.77 ^{b}
Potassium foliar application (K)						
K0	9.50 ^{a}	3.89 ^{a}	146.08 ^{a}	4.23 ^{b}	1.57 ^{c}	56.83 ^{b}
K1	9.87 ^{a}	3.83 ^{a}	134.23 ^{a}	4.72 ^{b}	2.81 ^{b}	74.64 ^{a}
K2	9.27 ^{a}	3.76 ^{a}	133.42^a	7.18 ^{a}	3.79 ^{a}	154.03 ^{a}
Cultivar						
Marvdasht	9.85 ^{a}	3.97^a	147.20 ^{a}	5.24 ^{ab}	2.72 ^{a}	92.64 ^{a}
Pishtaz	9.96 ^{a}	3.77 ^{a}	136.78 ^{a}	6.33 ^{a}	2.69 ^{a}	97.77 ^{a}
WS-82-9	8.82 ^{a}	3.74 ^{a}	129.75 ^{a}	4.38 ^{a}	2.76 ^{a}	95.09 ^{a}

Means with the same letter in each column have not statistically significant difference.

Spraying wheat plants with 3.0 % K2O produced the highest values of physiological indices followed by spraying plants with 1.5 % K2O; while control treatment (without potassium foliar application) gave the lowest values of these characters (Table 2). This improvement in physiological indices due to potassium foliar application may be ascribed to the role of potassium in improving many physiological growth processes and delay plant leaves senescence as well as increasing photosynthetic activity. These results are in line with those stated by Abou El-Defan *et al.* (1999) and El-Sabbagh *et al.* (2002) [15, 16]. Effect of water stress (low, mild and severe) and K supply (0.2, 2.0 and 6.0 mM) on net photosynthesis rate in wheat leaves was studied by Sen Gupta *et al*., (1989) [17]. Result showed under water stress, the photosynthetic efficiency of plants was reduced drastically (61%) as a consequence of chloroplast dehydration. Also, in drought stress conditions, spraying plants with K application in three levels 0.2, 2.0 and 6.0 mM, photosynthesis rate increased 17.3%, 75% and 92.8%, respectively. In wheat experiments, Pier and Berkowitz, (1987) observed 66-113% higher photosynthetic rates in plants fertilized with above normal K+ than those under standard fertilization, indicating that leaves of plants grown in very high internal K+ levels have partially reversed the dehydration effects on photosynthesis [18]. The function of stomata is to control water loss from the plant via transpiration. When K+ is deficient, the stomata can not function properly and water losses from plant may reach damaging levels [19]. Significant impact of wheat cultivars on net photosynthesis was observed (Table 1). Pishtaz cultivar produced the highest net photosynthesis compared to the other cultivars (Table 2). Difference between cultivars in physiological indices was reported by other researcher [1].

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